Towards Recyclable Insulation Materials for High Voltage Cables

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The preferred material for modern extruded high voltage transmission cables is cross-linked polyethylene (XLPE). This material has excellent thermo-mechanical and dielectric properties, however it is not easily recycled at end of use, raising questions as to its long term sustainability [1]. Therefore research work at Southampton has sought to identify suitable recyclable alternatives to XLPE. Such candidate materials need to have low temperature flexibility and high temperature mechanical stability combined with a sufficiently high electrical breakdown strength.

Initially ethylene based systems [2] were considered, however, low density polyethylene (LDPE) has poor mechanical stability at temperatures exceeding 80 ^{o}C whereas high density polyethylene (HDPE) is too brittle at low temperatures. To overcome these difficulties, a series of blends combining either an ethylene vinyl acetate (EVA) co-polymer or a low density polyethylene (LDPE) with a high density polyethylene (HDPE) were considered. A blend of 20 % HDPE in LDPE crystallised relatively rapidly (Figure 1a), was found to offer a good balance between high temperature mechanical stability and flexibility at low temperatures (Figure 1b) combined with excellent dielectric strength. In the remaining EVA based blends, increasing the vinyl acetate content resulted in a more rubbery composite but with a reduced high temperature stability and breakdown strength.

Propylene based systems were then considered, these included traditional syndiotactic (sPP) and isotactic polypropylene (iPP) and a range of propylene-ethylene co-polymers. Such systems offered enhanced high temperature stability and with sufficient ethylene content, low temperature flexibility [3], combined with good dielectric breakdown strength provided that the crystallisation was rapid enough to avoid the formation of large spherulites. In further efforts to optimise the properties, two blend systems composed of iPP mixed with either a propylene ethylene co-polymer (with 40 % ethylene content; "PE40") or sPP were considered. Provided that the crystallisation was relatively rapid, both blends provided excellent dielectric performance and high temperature stability. A blend of 20 % iPP in PE40 (Figure 1c) offers the best level of mechanical flexibility at low temperatures and would therefore be suitable for the manufacture of enhanced, recyclable high voltage cables.

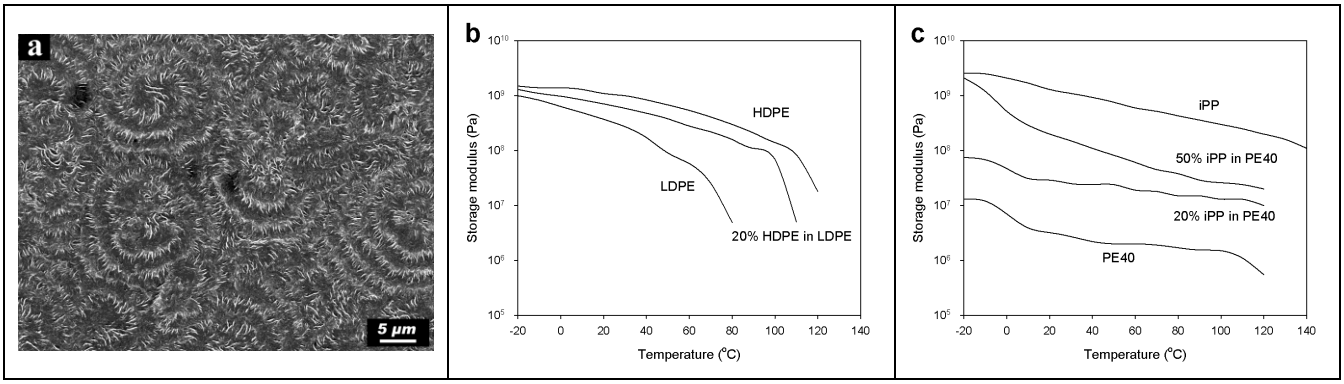

Figure 1: (a) Morphology of the optimised LDPE/HDPE blend system (b) mechanical properties of selected ethylene based systems (c) mechanical properties of iPP, PE40 and its blends

[1] C. P. Martin, "The impact of mechanical stress on the integrity of XLPE cables", PhD Thesis, University of Southampton, 2004.

[2] I. L. Hosier, A. S. Vaughan and S. G. Swingler, "An investigation of the potential of ethylene vinyl acetate/polyethylene blends for use in recyclable high voltage cable insulation systems", , *J. Mat. Sci*., vol. 45, no. 10, pp. 2747-2459, 2010.

[3] I. L. Hosier, L. Cozzarini, A. S. Vaughan and S. G. Swingler, "Propylene based systems for high voltage cable insulation applications", *J. Phys.: Conf. ser.*, vol. 183, 012015, 2009.